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A. Stephen Morse

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Research under this grant has focussed on adaptive control of multivariable systems.

Seventeen papers were published under this grant, involving Adaptive Stabilization of Linear System with Unknown High-Frequency Gains and Indirect Adaptive Control of Processes satisfying the Classical Assumptions of Direct Adaptive.

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22a. NAME OF RESPONSIBLE INDIVIDUAL

Major James M. Crowley

22b. TELEPHONE (Include Area Code)

(202) 767-5025

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ADAPTIVE CONTROL OF MULTIVARIABLE SYSTEMS

FINAL SCIENTIFIC REPORT

for the period

July 15, 1984 to July 14, 1988

Submitted to the

UNITED STATES AIR FORCE  
OFFICE OF SCIENTIFIC RESEARCH

under

AFOSR GRANT NO. 84-0242

A. Stephen Morse, Principal Investigator

October 6, 1988



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## I. INTRODUCTION

This is the final scientific report for AFOSR Grant No. 84-0242 covering the period July 15, 1984 to July 14, 1988. The work described below was undertaken in accordance with our previously submitted proposals.

## II. COMPLETED WORK

### A. Research Reports and Papers

During the grant period, research leading to the following technical reports and papers was completed.

- [1] A. S. Morse, "New Directions in Parameter Adaptive Control,"  
Proc. 1984 IEEE Conf. on Decision and Control, Dec. 1984.
- [2] D. R. Mudgett and A. S. Morse, "Adaptive Stabilization of Linear  
Systems with Unknown High-Frequency Gains," IEEE Trans. Auto.  
Control, June 1985, also Proc. 1984 IEEE Conf. on Decision and  
Control, Dec. 1984.
- [3] D. R. Mudgett and A. S. Morse, "A Smooth Algorithm for Adaptive  
Stabilization of a Discrete Linear System with an Unknown High  
Frequency Gain," Proc. 1985 ACC, June 1985.
- [4] A. S. Morse, "A  $4(n+1)$ -Dimensional Model Reference Adaptive Control  
for the Stabilization of Any Strictly Proper Minimum Phase Linear  
System with Relative Degree Not Exceeding Two and Dimension Not  
Exceeding  $n$ ," Proc. 7th Int. Symp. on the Math. Theory of Networks  
and Systems, Stockholm, June 1985; also Automatica, January 1987.
- [5] D. R. Mudgett and A. S. Morse, "Adaptive Stabilization of a Discrete  
Linear System with an Unknown High-Frequency Gain," IEEE Trans. Auto.  
Control, Aug. 1985.
- [6] A. S. Morse, "A Three-Dimensional Universal Controller for the  
Adaptive Stabilization of Any Strictly Proper Minimum-Phase System  
with Relative Degree Not Exceeding Two," IEEE Trans. Auto. Control,  
December 1985.

- [7] C. I. Byrnes, U. Helmke and A. S. Morse, "Necessary Conditions in Adaptive Control," Proc. 7th Int. Symp. on the Math. Theory of Networks and Systems, Stockholm, June 1985.
- [8] A. S. Morse, "Simple Algorithms for Adaptive Stabilization," Proc. I.I.A.S.A. Conference on Modelling and Adaptive Control, Sopron, Hungary, July 1986.
- [9] A. S. Morse, "State Estimation Using Distributed Processing," Proc. IEEE Conf. on Decision and Control, Athens, December 1986.
- [10] D. R. Mudgett and A. S. Morse, "High-Order Parameter Adjustment Laws for Adaptive Stabilization," Proc. 1987 Johns Hopkins CISS Conf., Feb. 1987.
- [11] A. S. Morse, "High-Gain Feedback Algorithms for Adaptive Stabilization," Proc. Fifth Yale Workshop on Applications of Adaptive Systems Theory, May 1987.
- [12] "Adaptive Stabilization by High Gain Feedback," Systems and Control Letters, to be submitted.
- [13] A. S. Morse, "Towards a Unified Theory of Parameter Adaptive Control - Part I: Tunability," Proc. 1988 CDC, Austin, Texas; IEEE Trans. Auto. Control, to appear.
- [14] A. S. Morse, "Towards a Unified Theory of Parameter Adaptive Control - Part II: Certainty Equivalence and Regulated Systems," IEEE Trans. Auto. Control, to appear.
- [15] A. S. Morse, "Indirect Adaptive Control of Processes Satisfying the Classical Assumptions of Direct Adaptive Control," Proc. 1988 ACC, Atlanta.
- [16] J. Huang and A. S. Morse, "A Computer Study of Adaptive Control Systems," Proc. 1988 ACC, Atlanta.
- [17] D. R. Mudgett, "Problems in Parameter Adaptive Control," Doctoral Dissertation, Yale University, 1988.

## B. Presentations

During the grant period the following presentations were made at technical meetings.

- [1] A. S. Morse, "New Directions in Parameter Adaptive Control," IEEE Conf. on Decision and Control, Dec. 1984.
- [2] D. R. Mudgett and A. S. Morse, "Adaptive Stabilization of Linear Systems with Unknown High-Frequency Gains," IEEE Conf. on Decision and Control, Dec. 1984.
- [3] D. R. Mudgett and A. S. Morse, "A Smooth Algorithm for Adaptive Stabilization of a Discrete Linear System with an Unknown High Frequency Gain," 1985 ACC, June 1985.
- [4] A. S. Morse, "A  $4(n+1)$ -Dimensional Model Reference Adaptive Control for the Stabilization of Any Strictly Proper Minimum Phase Linear System with Relative Degree Not Exceeding Two and Dimension Not Exceeding  $n$ ," 7th Int. Symp. on the Math. Theory of Networks and Systems, Stockholm, June 1985.
- [5] C. I. Byrnes, U. Helmke and A. S. Morse, "Necessary Conditions in Adaptive Control," 7th Int. Symp. on the Math. Theory of Networks and Systems," Stockholm, June 1985.
- [6] A. S. Morse, "Simple Algorithms for Adaptive Stabilization," I.I.A.S.A. Conference on Modelling and Adaptive Control, Sopron, Hungary, July 1986.
- [7] A. S. Morse, "State Estimation Using Distributed Processing," IEEE Conf. on Decision and Control, Athens, December 1986.
- [8] D. R. Mudgett, "High-Order Parameter Adjustment Laws for Adaptive Stabilization," 1987 Johns Hopkins CISS Conf., Feb. 1987.
- [9] A. S. Morse, "High-Gain Feedback Algorithms for Adaptive Stabilization," Fifth Yale Workshop on Applications of Adaptive Systems Theory, May 1987.
- [10] A. S. Morse, "Adaptive Stabilization by High-Gain Feedback," 1987 MTNS Conf., Phoenix, June 1987.

- [11] A. S. Morse, "Indirect Adaptive Control of Processes Satisfying the Classical Assumptions of Direct Adaptive Control," 1988 ACC, Atlanta.
- [12] J. Huang and A. S. Morse, "A Computer Study of Adaptive Control Systems," 1988 ACC, Atlanta.

C. Miscellaneous

- [1] Doctoral Student: One graduate student successfully completed his doctoral research under AFOSR support:
- David Mudgett, "Problems in Parameter Adaptive Control, October 1988.